STRATAFORM PLUME STUDY: Analyses of Mooring Data and Associated Tasks

James F. Lynch
James D. Irish
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
phone:: (508) 289-2230 fax: (508) 457-2194 email: jlynch@whoi.edu
phone: (508) 289-2732 fax: (508) 457-2154 email: jirish@whoi.edu
Award Number: N00014-97-1-0331
http://penguin.whoi.edu/strataform/Strataform96.html

LONG-TERM GOALS

The overall goal of the ONR STRATAFORM program is to advance our understanding of the formation of stratigraphic sequences on continental shelves and slopes. Our research program focuses on identifying and quantifying sediment erosion, transport, and deposition processes on the continental shelf through state of the art observational techniques in both fine-grained and sandy environments. In sandy environments our goal is to understand the detailed interactions and feedback between hydrodynamics, bedforms, and the resulting sand transport. In fine-grained environments, we have been investigating the role of fluid mud flows as a cross-shore transport mechanism.

OBJECTIVES

The primary objective of this project is to analyze bottom boundary layer tripod data and water column mooring data taken during the winter of 1997-1998 at Eel River STRATAFORM site. This site is particularly interesting because there is a large source of fine-grained sediment, the Eel river, during winter flood events. The river plume has been shown to deliver sediment only to the inner shelf; however, the final deposit of the riverine sediment is located on the mid-shelf, seaward of the 50 m isobath. Bottom tripod data has shown that a large amount of sediment, initially placed by the plume inshore of the midshelf patch, was transported seawards in the bottom boundary layer by low concentration suspended sediment transport forced by mean currents [*Cacchione et al*., 1998]. However, our acoustic backscatter sensor, combined with a vertical array of velocity measurements, revealed that during these periods of offshore transport of fine sediment from the inner shelf to the deposition area, high concentration fluid mud layers can form near the seabed. Thus the data from our 1997-1998 deployment was used to examine the role of low concentration suspended sediment transport by mean currents vs the role of down-slope flow of thin fluid mud layers as cross-shelf transport mechanisms.

A secondary objective of this project is to look at how the detailed stratigraphic mapping which has been performed in STRATAFORM can be incorporated into low frequency (10-1000 Hz) acoustic propagation models, which have immediate naval importance. A good interface between the detailed geology and acoustics applications needs to be created, and given the unique, high quality stratigraphic data for the top 100m of sediment that are available through STRATAFORM, it is an ideal place to start.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE
30 SEP 1999

2. REPORT TYPE

3. DATES COVERED
00-00-1999 to 00-00-1999

4. TITLE AND SUBTITLE
STRATAFORM PLUME STUDY: Analyses of Mooring Data and Associated Tasks

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Woods Hole Oceanographic Institution,Woods Hole,MA,02543

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

APPROACH

The observational program consisted of a cross shore array of three bottom boundary layer monitoring tripods and three water column moorings spanning cross shelf distance from the inner shelf (20 m isobath) to the mud deposit region (60 m isobath). This, combined with the rapid response program of Geyer et al., allowed simultaneous measurements of water velocity and the vertical structure of sediment concentration in both the Eel River plume and in the bottom boundary layer between the inner shelf and the deposit region. Unfortunately, the central tripod was buried and could not be recovered. The inner shelf tripod was also buried, but was recovered. The outer tripod produced a high quality data set, which has been the focus of our analysis efforts.

The approach used in analyses of the data consisted of first examining the sequence of events on the inner shelf by using the time series available from the moorings, combined with OBS casts and water bottle samples from the rapid response program. This sets the initial condition for cross-shelf transport events. The second part of the analyses consisted of examining the data from the outer tripod to investigate transport processes at the deposit region. The observations of cross shore transport processes are initially being examined in terms of first order physical forcing mechanisms. In planned work, we will investigate the use of a 2-d cross shelf numerical model to simulate the transport events.

Regarding our secondary objective, we have initially focused on using “remnant river bed” surveys from the east coast STRATAFORM as the geological entity of interest. Using chirp sonar data provided by N. Driscoll, we are inputting the detailed geological profiles into standard acoustic propagation models, such as adiabatic and coupled mode codes and parabolic equation codes. We are initially studying forward propagation and array coherence with this data, using both standard formalisms and a new approach (the “modal phase structure function”) we have developed at WHOI. We eventually would like to extend this work to include reverberation (which is an important aspect of the remnant river beds, i.e. they are strong “false targets”), uncertainty in the geoacoustic models, and other types of stratigraphic features.

WORK COMPLETED

The analyses discussed have resulted in two papers, which have been submitted for publication this year. The first is entitled “Dynamics of Cross-Shelf Sediment Transport, Northern California Shelf: Role of High and Low Concentration Suspensions in the Formation of “Flood” Beds” (Swift et al., 1999) Our role in this paper was to provide observations and analyses related to the formation of high-concentration fluid mud layers and to elucidate the role of sediment induced stratification in maintaining these layers. The second paper describes the observations from the 1997-98 deployment. This paper examines the events on the inner shelf which lead to the formation of the fluid mud layers observed at the mid shelf deposit region. The observations of down-slope flows of fluid mud are described in detail, along with analysis of the dynamics of the forcing mechanisms for these layers.

The work on the interaction of the geology with acoustic propagation has yet to be published, but has recently been presented at the 138th meeting of the Acoustical Society of America.

RESULTS

The primary result of this work has been to identify the presence of down-slope flow of fluid mud as an important mechanism for transporting sediment from the inner shelf, where it is initially placed by the Eel river plume, to the final deposit region located at mid-shelf. The observations on the inner shelf reveal a dramatic accumulation of sediment on the inner shelf during high river discharge events. For a short period (generally lasting up to several days, depending on exact timing of the discharge events) offshore transport processes are not able to remove sediment from the inner shelf as fast as it is being supplied by the river plume. However, once suspended sediment concentration become high enough, which requires large amounts of wave energy to resuspend or keep the sediment in suspension, down-slope flows of fluid mud carry the sediment offshore. These down-slope flows were observed with an acoustic backscattering sensor (ABS) and a vertical array of current meters. The ABS also showed that depositional events of up 13 cm were associated with these flows. In fact, ALL of the depositional events observed at the tripod location were associated with fluid mud flows; erosional events of up to 6 cm were observed during periods of dominantly along shore transport of low concentration suspended sediment. Thus it is hypothesized that these fluid mud flows are the dominant mechanism in producing the mid-shelf mud deposit.

The thickness of the fluid mud layer scales with the wave boundary layer thickness in a temporally coherent manner, and the fluid mud layer is only present during periods of high wave energy. Thus it appears that the down slope fluid mud flows observed on the mid shelf at the STRATAFORM site are not the "auto-resuspending" turbidity currents described in the literature. Rather, they are wave induced turbidity currents which require wave energy to remain in suspension. The stratification at the top of the wave boundary layer allows a high enough sediment concentration to develop to provide sufficient gravitational forcing to create a down-slope flow. Since the fluid mud layer thickness is proportional to the wave boundary layer height as the flow travels across the shelf into deeper water, the wave energy decreases and the carrying capacity of the fluid mud flow decreases. Preliminary investigations of this show that the wave energy is insufficient to carry the fluid mud flows past the 90m isobath, which is the offshore boundary of the mid-shelf mud deposit. Further modeling work is being conducted to investigate the thickness and location of deposits from these fluid mud flows. This mechanism does not provide an explanation for the location of the inshore boundary of the mud deposit. The thickness of the initial deposition event and the amount of storm reworking during storms that don't have a large river discharge event may responsible for determining the ultimate fate of these deposits in the stratigraphic layer.

Regarding our secondary topic, results to date show that the remnant river beds indeed have a significant impact on the phase of the acoustic arrivals, and thus array coherence, but a lesser impact on propagation loss (an amplitude effect.)

IMPACT

The principal impact of this work to date is to reveal, through observations, that the dominant cross shelf transport mechanism off the Eel River is down-slope flows of wave induced turbidity currents. These observations revealed a transport and deposition mechanism that can explain the thick deposits of riverine sediment found on the mid shelf.

TRANSITIONS

The observed dynamics of the fluid mud flows will be incorporated into simple modeling efforts to describe the cross shelf transport and deposition due to these flows. This modeling will be based on the 1-d sediment resuspension , transport and deposition model developed by P. Wiberg. Ultimately these types of flows can added into more sophisticated two and three dimensional models to predict shelf sediment transport and better understand the stratigraphic record.

RELATED PROJECTS

The STATAFORM project provides a unique opportunity to study sediment dynamics in an environment that is dominated by fine sediment during periods of high river discharge. This project provides a sharp contrast to our work in other environments, such as LEO-15, which has medium-to-coarse grained sand [*Traykovski et al.*, 1999]. Yet, in both environments it has become apparent that adequately observing sediment concentration and velocity (to calculate transport) in the 10 cm nearest the seafloor is crucial to understanding the dominant mechanisms of sediment transport. We are conducting further work at the LEO-15 site this winter, and will also participate in deployments in the NY Bight, where we are joining a USGS effort to understand sediment transport in the Hudson Shelf Valley.

REFERENCES/PUBLICATIONS

Agrawal, Y.C. and P. Traykovski, "Particles in the Bottom Boundary Layer: Concentration and Size Dynamics through Events," submitted to J. Geophys. Res., 1999

Cacchione, D.A., P.L. Wiberg, J. Lynch, J. Irish and P. Traykovski, Estimates of suspended sediment flux and bedform activity on the inner portion of the Eel continental shelf, Marine Geology, 154, p. 83-97, 1999

Irish, J.D., J.F. Lynch, P. Traykovski, A.E. Newhall, K. Prada and A.E. Hay, "A Self Contained Sector Scanning Sonar for Bottom Roughness Observations as Part of Suspended Sediment Studies, In press, Jour. Atm. and Oceanic Tech, 1998.

Fan, S., D. J. P. Swift, P. Traykovski, S. Bentley, and C. W. Reed, Dynamics of Cross-Shelf Sediment Transport, Northern California Shelf: Role of High and Low Concentration Suspensions in the Formation of "Flood" Beds. Submitted to Continental Shelf Research, 1999

Traykovski, P., W. R. Geyer, J. D. Irish And J. F. Lynch, The Role of Density Driven Fluid Mud Flows for Cross-Shelf Transport on the Eel River Continental Shelf. Submitted to Continental Shelf Research, 1999

Traykovski, P., A.E. Hay, J.D. Irish and J.F. Lynch, "Geometry, migration and evolution of wave orbital scale ripples at LEO-15", J. Geophys. Res., vol 104, no C1, 1999

Traykovski, P., "Wave Forced Sediment Transport at the Sandy Inner Continental Shelf LEO-15 Site" submitted to J. Geophys. Res. 1998

Traykovski, P., R.J. Latter and J.D. Irish, “A laboratory evaluation of the LISST instrument using natural sediments”, Marine Geology, 159, p. 355-367, 1999